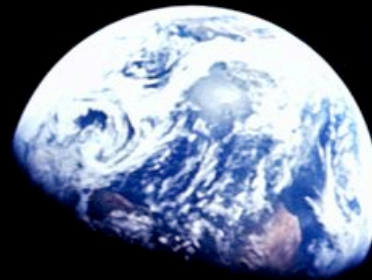




Developing a Framework for Climate Literacy:

The Case for Climate Literacy in the 21st Century



Frank Niepold
National Oceanic and Atmospheric Administration
Climate Program Office,
Washington, D.C., USA



A Private Universe Project

How well do US college graduates understand important science ideas?



1. A seed grows into a large tree. Where did the mass of the tree come from?
2. What if I told you that the mass comes mainly from the carbon dioxide in the air?



Climate Literacy

What does a climate literate citizen look like?

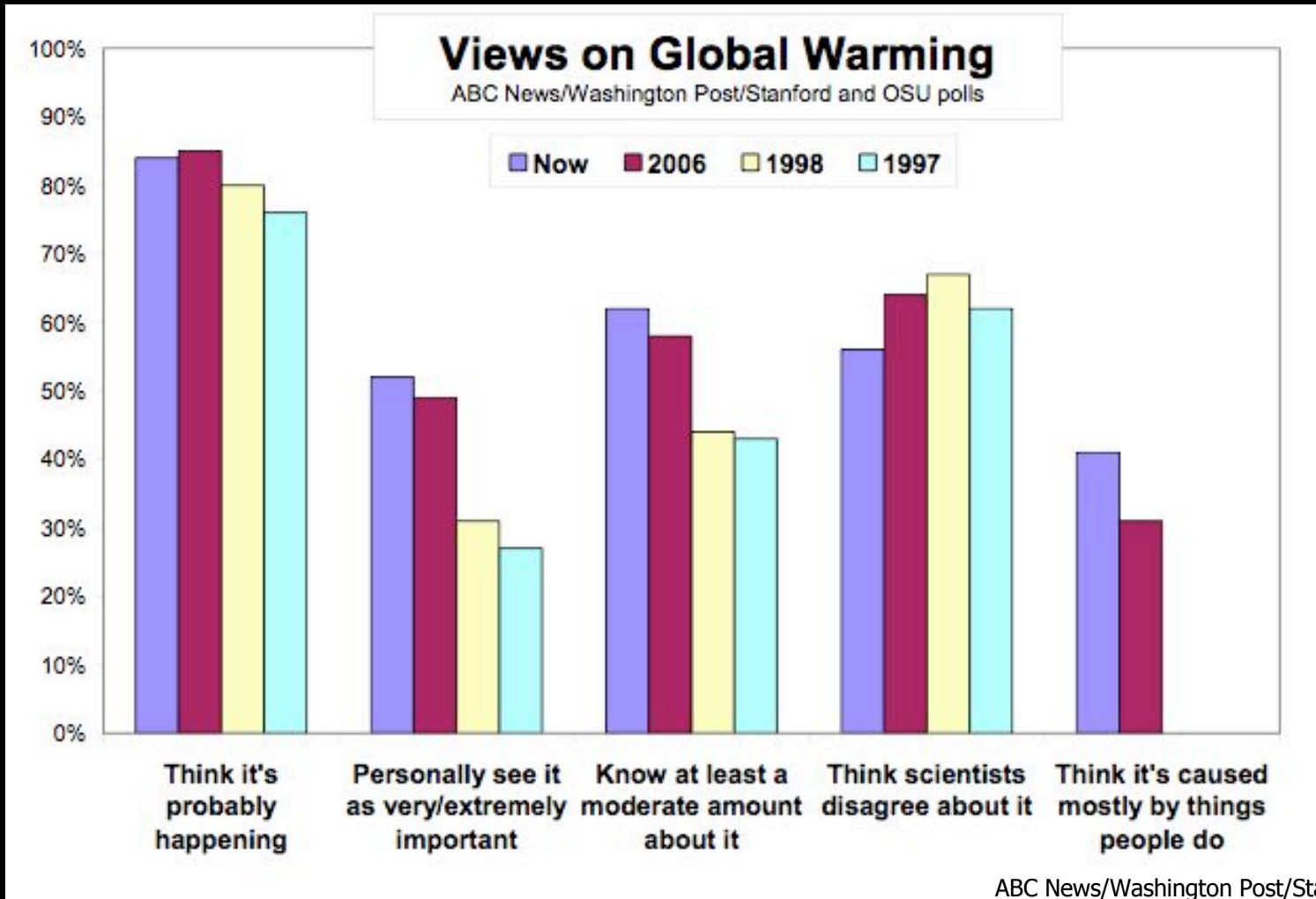
How would a climate literate citizen make informed decisions?

How can we assist in ensuring climate literate citizens?

How can we support climate literate citizen's so they are able to make informed decisions?



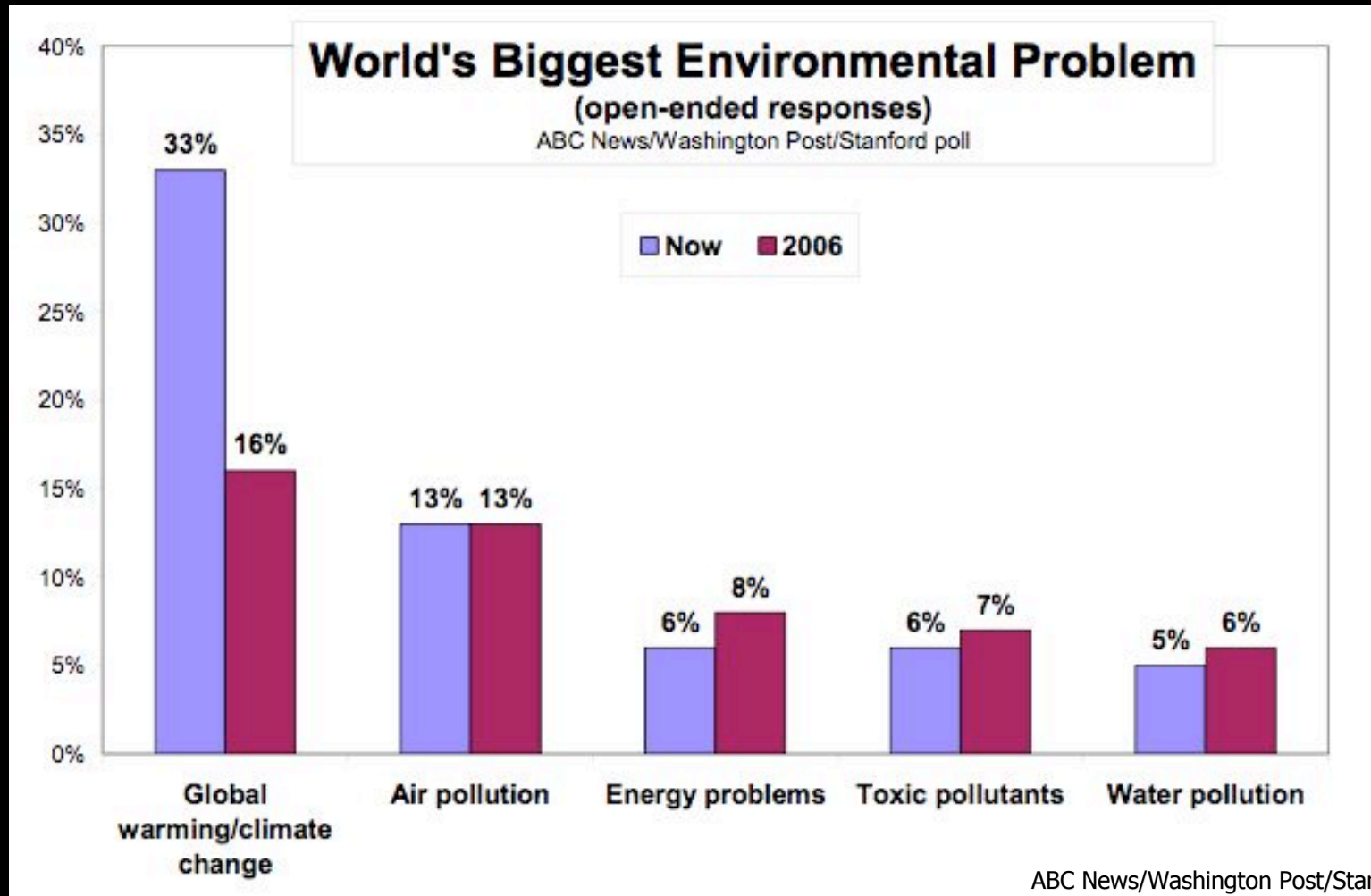
Where Is The Public?



ABC News/Washington Post/Stanford and OSU



Where Is The Public?



ABC News/Washington Post/Stanford and OSU



Effective Communications about Global Warming

Existence

Attitudes

Certainty

Human Responsibility

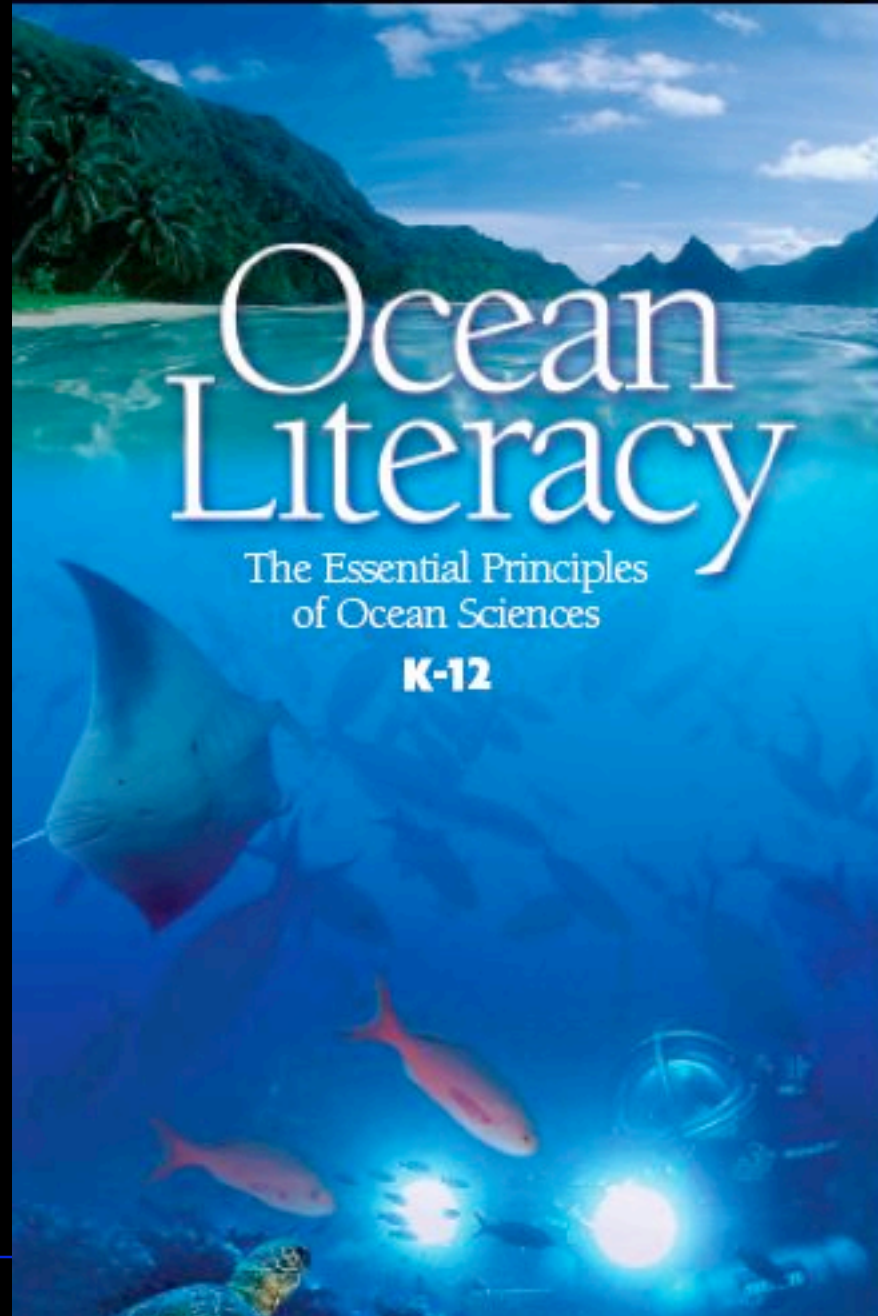
People's Ability To Remedy It

AN OCEAN-ORIENTED APPROACH TO
TEACHING SCIENCE STANDARDS

Ocean Literacy

The Essential Principles
of Ocean Sciences

K-12



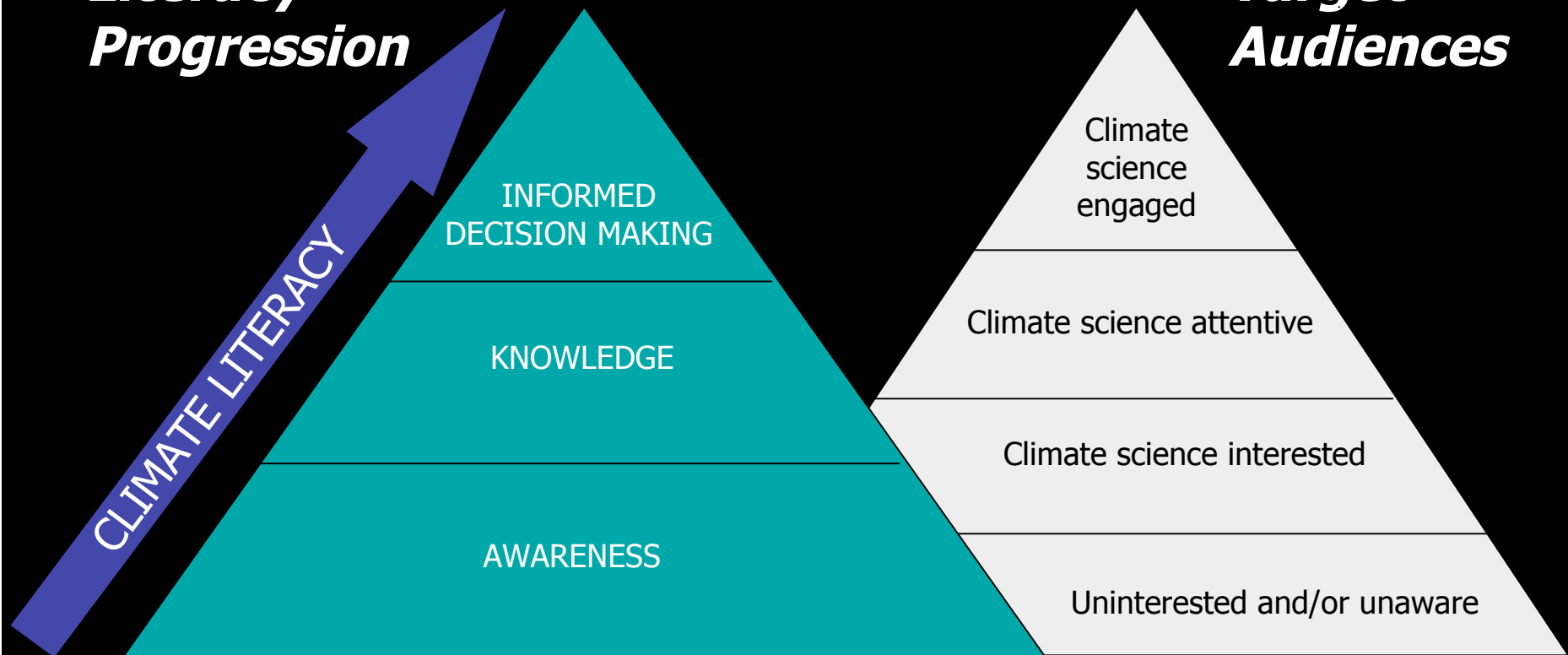


Climate Literacy is...

- **...a continuum of competency**

***Literacy
Progression***

***Target
Audiences***



Long-term, the vision expects a society capable of informed decision-making



A T L A S

O F S C I E N C E L I T E R A C Y

VOLUME 2



AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

PROJECT 2061

ATLAS OF SCIENCE LITERACY, VOLUME 1 AND VOLUME 2 COMBINED TABLE OF CONTENTS

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Tables and page numbers printed in green indicate maps in Volume 2; those printed in gray indicate maps in Volume 1.

The earth's climates have changed in the past, are currently changing, and are expected to change in the future, primarily due to changes in the amount of light reaching places on the earth and the composition of the atmosphere. The burning of fossil fuels in the last century has increased the amount of greenhouse gases in the atmosphere, which has contributed to earth's warming. 4B/H6** (SFAA)

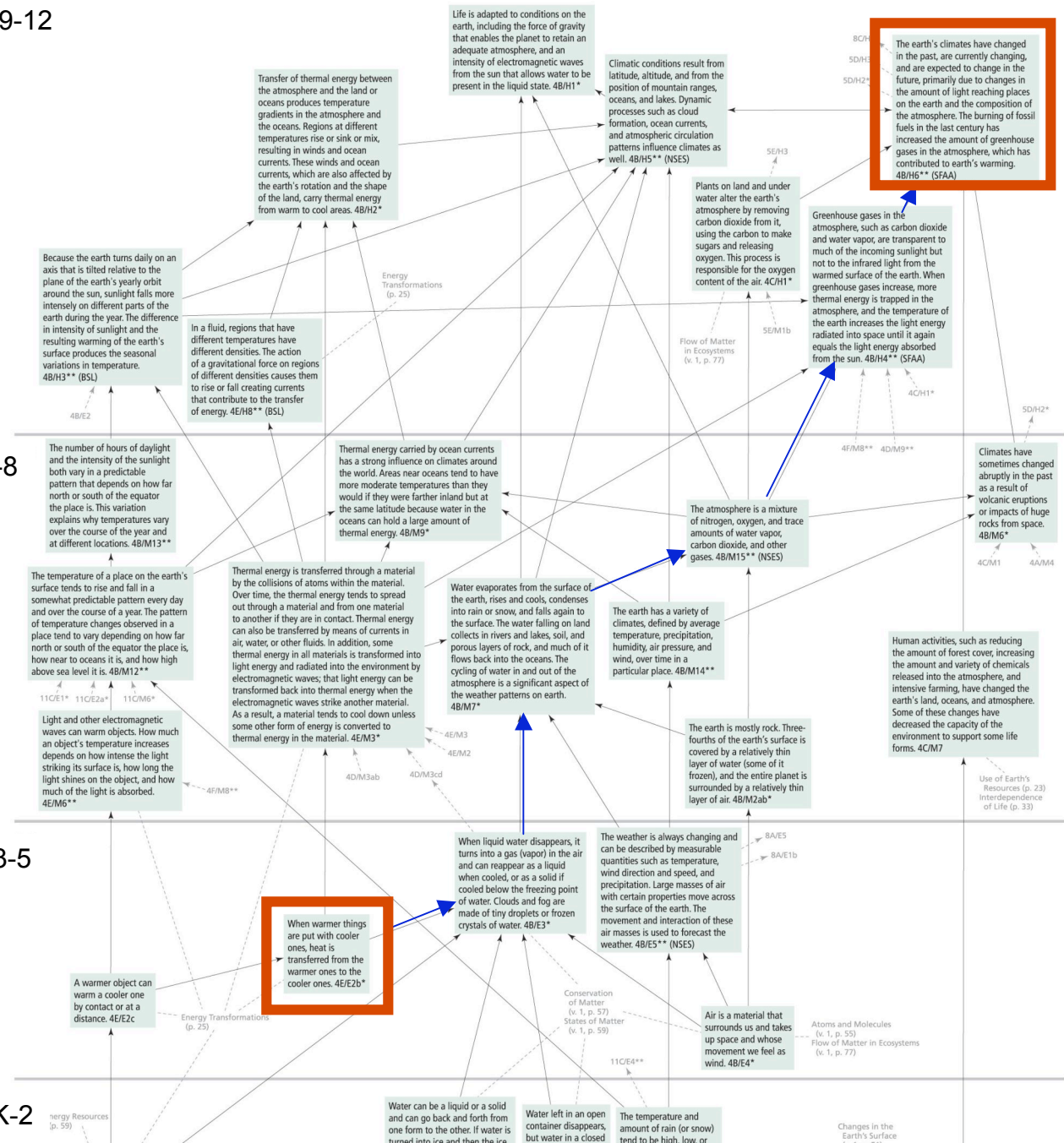
When warmer things are put with cooler ones, heat is transferred from the warmer ones to the cooler ones. 4E/E2b*

9-12

6-8

3-5

K-2



WEATHER AND CLIMATE (4B)

Benchmarks in this map about temperature and winds draw on ideas about heat transfer and transformation in the **ENERGY TRANSFORMATIONS** map. Benchmarks in the *climate change* strand are also related to the **SCIENCE AND SOCIETY** map. The widespread use of climate models to improve our understanding of the earth's climate system and climate change suggests a connection to benchmarks in the **MODELS** map as well.

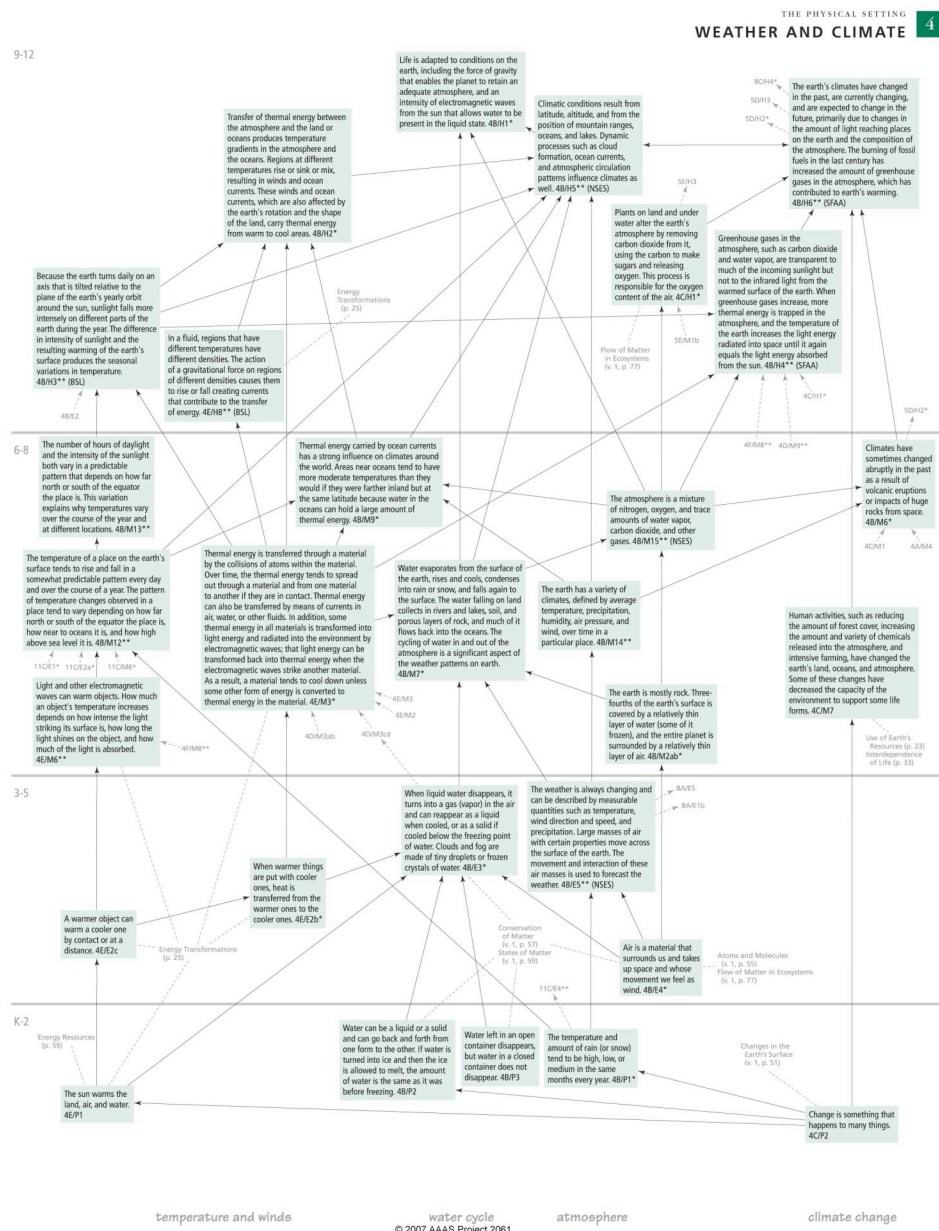
The left-hand side of the *temperature and winds* strand presents a progression of understanding of seasons. The explanation of the seasons in terms of the tilt of the earth requires students to engage in fairly complex spatial reasoning. For this reason, although the idea is introduced at the 6-8 grade level in *Benchmarks*, the map places it (4B/H3) at the 9-12 level.

Several lines of conceptual development converge in the new 9-12 benchmark that begins "Climatic conditions result from..." These include an understanding of temperature patterns over the earth, atmospheric and oceanic circulation patterns, and the water cycle. A double-headed arrow between this benchmark and another new benchmark (4B/H6) on climate change indicates that they are closely related but that neither is conceptually dependent on the other.



Students of all ages may confuse the ozone layer with the greenhouse effect, and may have a tendency to imagine that all environmentally friendly actions help to solve all environmental problems (for example, that the use of unleaded petrol reduces the risk of global warming) (Andersson & Wallin, 2000; Koulaidis & Christidou, 1998; Meadows & Wiesenmayer, 1999; Rye, Rubba, & Wiesenmayer, 1997). Students have difficulty linking relevant elements of knowledge when explaining the greenhouse effect and may confuse the natural greenhouse effect with the enhancement of that effect (Andersson & Wallin, 2000).

See **ENERGY RESOURCES** and **ENERGY TRANSFORMATIONS** for additional research.

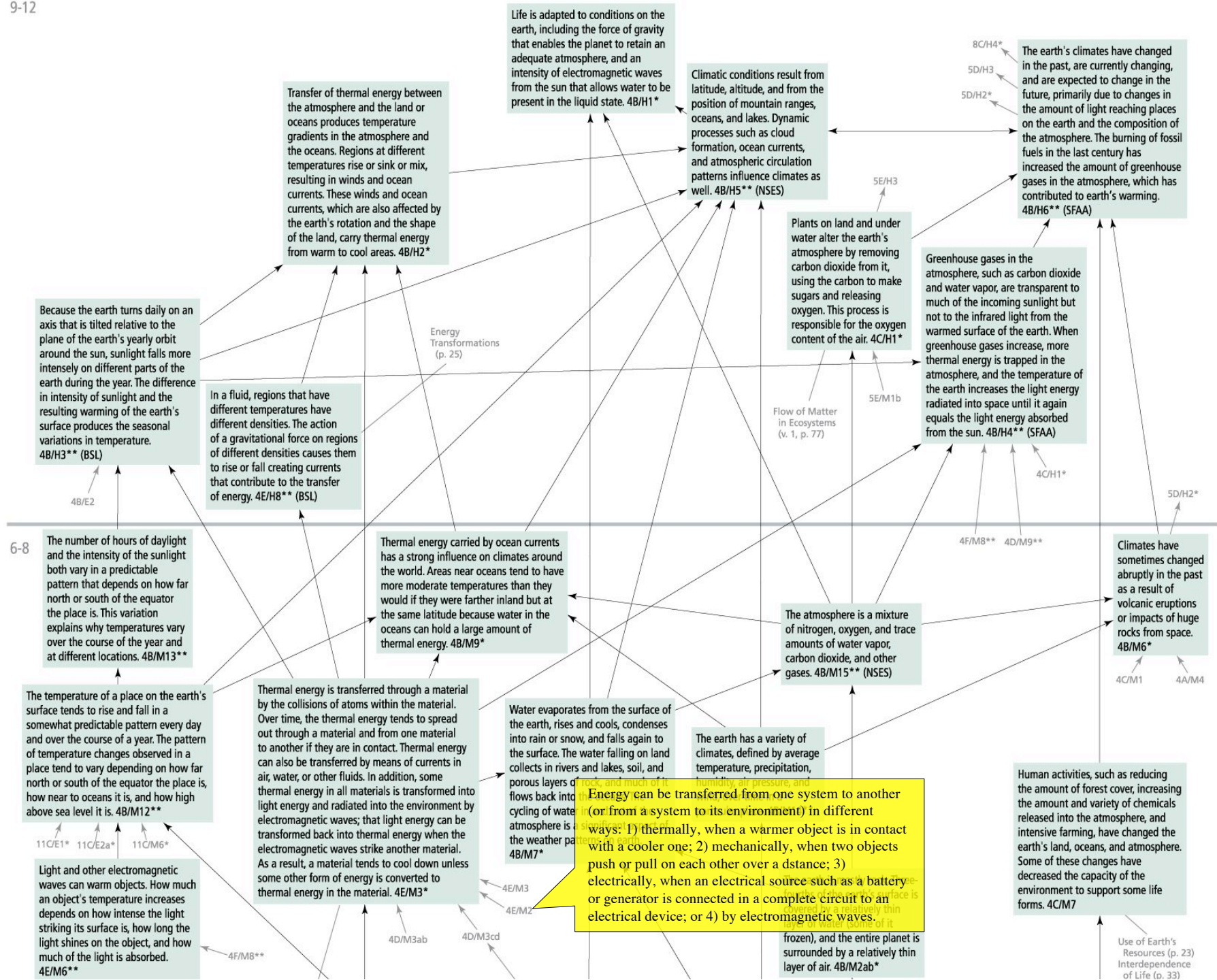


RESEARCH IN BENCHMARKS

Students of all ages (including college students and adults) have difficulty understanding what causes the seasons. Students may not be able to understand explanations of the seasons before they reasonably understand the relative size, motion, and distance of the sun and the earth (Sadler, 1987; Vosniadou, 1991). Many students before and after instruction in earth science think that winter is colder than summer because the earth is farther from the sun in winter (Atwood & Atwood, 1996; Dove, 1998; Philips, 1991; Sadler, 1998). This idea is often related to the belief that the earth orbits the sun in an elongated elliptical path (Galili & Lavrik, 1998; Sadler, 1998). Other students, especially after instruction, think that the distance between the northern hemisphere and the sun changes because the earth leans toward the sun in the summer and away from the sun in winter (Galili & Lavrik, 1998; Sadler, 1998). Students' ideas about how light travels and about the earth-sun relationship, including the shape of the earth's orbit, the period of the earth's revolution around the sun, and the period of the earth's rotation around its axis, may interfere with students' understanding of the seasons (Galili & Lavrik, 1998; Salierno, Edelson, & Sherin, 2005). For example, some students believe that the side of the sun not facing the earth experiences winter, indicating a confusion between the daily rotation of the earth and its yearly revolution around the sun (Salierno, Edelson, & Sherin, 2005).

temperature and progression of
i. The explanation of the tilt of the earth
ge in fairly complex reason, although
the 6-8 grade level places it (4B/H3)

the heating of materi-
ermal energy lay the
or understanding
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rate, and the effect
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Communicating and Learning About Global Climate Change

An Abbreviated Guide for Teaching Climate Change,
from Project 2061 at AAAS



©Lonnie Thompson/Ohio State University



- WEATHER AND CLIMATE
- USE OF EARTH'S RESOURCES
- ENERGY RESOURCES
- INTERDEPENDENCE OF LIFE
- SCIENTIFIC INVESTIGATIONS
- INTERACTION OF TECHNOLOGY AND SOCIETY
- DECISIONS ABOUT USING TECHNOLOGY
- PATTERNS OF CHANGE
- MORE TO COME...



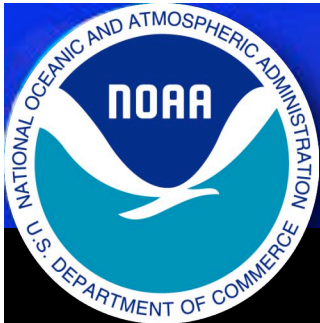


Framework for Climate & Weather Education Workshop Summary Report



April 11-13, 2007





A CLIMATE-ORIENTED APPROACH
TO TEACHING SCIENCE STANDARDS

CLIMATE LITERACY

ESSENTIAL PRINCIPLES
AND FUNDAMENTAL
CONCEPTS

EACH ESSENTIAL PRINCIPLE IS SUPPORTED BY FUNDAMENTAL CONCEPTS
COMPARABLE TO THOSE UNDERLYING THE NATIONAL SCIENCE EDUCATION STANDARDS (NSES)
AND AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE (AAAS) BENCHMARKS.
CONSULT THE **OVERVIEW MATRIX** (UNDER DEVELOPMENT) TO INTEGRATE CLIMATE LITERACY
INTO YOUR CURRICULUM.

1

Life on Earth has been shaped by, depends on, and affects climate.

2

We understand the climate system through observation and modeling.

LIFE & CLIMATE

- a. All organisms include changes in their environment.
- b. Changes in ecosystems, very large changes in ecosystems. (Based on AAAS, 5D/H1)
- c. Changes in environmental conditions can affect the survival of individual organisms and entire species. (Based on AAAS, 5F/M2b)
- d. Human societies have developed food, energy, transportation, and social systems that are dependent on climate and vulnerable to climate changes.
- e. These human systems have developed during a relatively stable period in Earth's climate history.
- f. Life on Earth and human activities influence climate, sometimes substantially.

No matter how well one theory fits observations, a new theory might fit them just as well or better, or might fit a wider range of observations. In science, the testing, revising, and occasional discarding of theories, new and old, never ends. This ongoing process leads to an increasingly better understanding of how things work in the world but not to absolute truth. Evidence for the value of this approach is given by the improving ability of scientists to offer reliable explanations and make accurate predictions. (AAAS, 1A/H3)

b. Fundamental characteristics of the climate system are understood well enough to support decision-making, even though research continues into many dynamics of climate change. (Based on AAAS, 12A/H3)

c. Data gathered through observations from weather stations, buoys, satellites, ice cores, tree rings, cave deposits, and other sources provide an understanding of past climates and climate changes.

d. Using observations, logic, and experiments to construct and refine computer models and scientific explanations leads to better understanding of the climate system's behavior and more reliable predictions. (Based on AAAS, 1B/H6)

There is a danger of choosing only the data that show what is expected by the person doing the choosing. (AAAS, 9D/E5c)

Source: Ryan Vachon, CIRES Outreach, (303) 735-3641



Source: Forrest M. Mims III, Geronimo Creek Observatory, (830) 372-0548



WEATHER AND CLIMATE

Climate Literacy
Essential Principle 5/
Fundamental Concept G

adapted to conditions on the
including the force of gravity
ables the planet to retain an
ite atmosphere, and an
y of electromagnetic waves
ie sun that allows water to be
: in the liquid state. 4B/H1*

Climatic conditions result from
latitude, altitude, and from the
position of mountain ranges,
oceans, and lakes. Dynamic
processes such as cloud
formation, ocean currents,
and atmospheric circulation
patterns influence climates as
well. 4B/H5** (NSES)

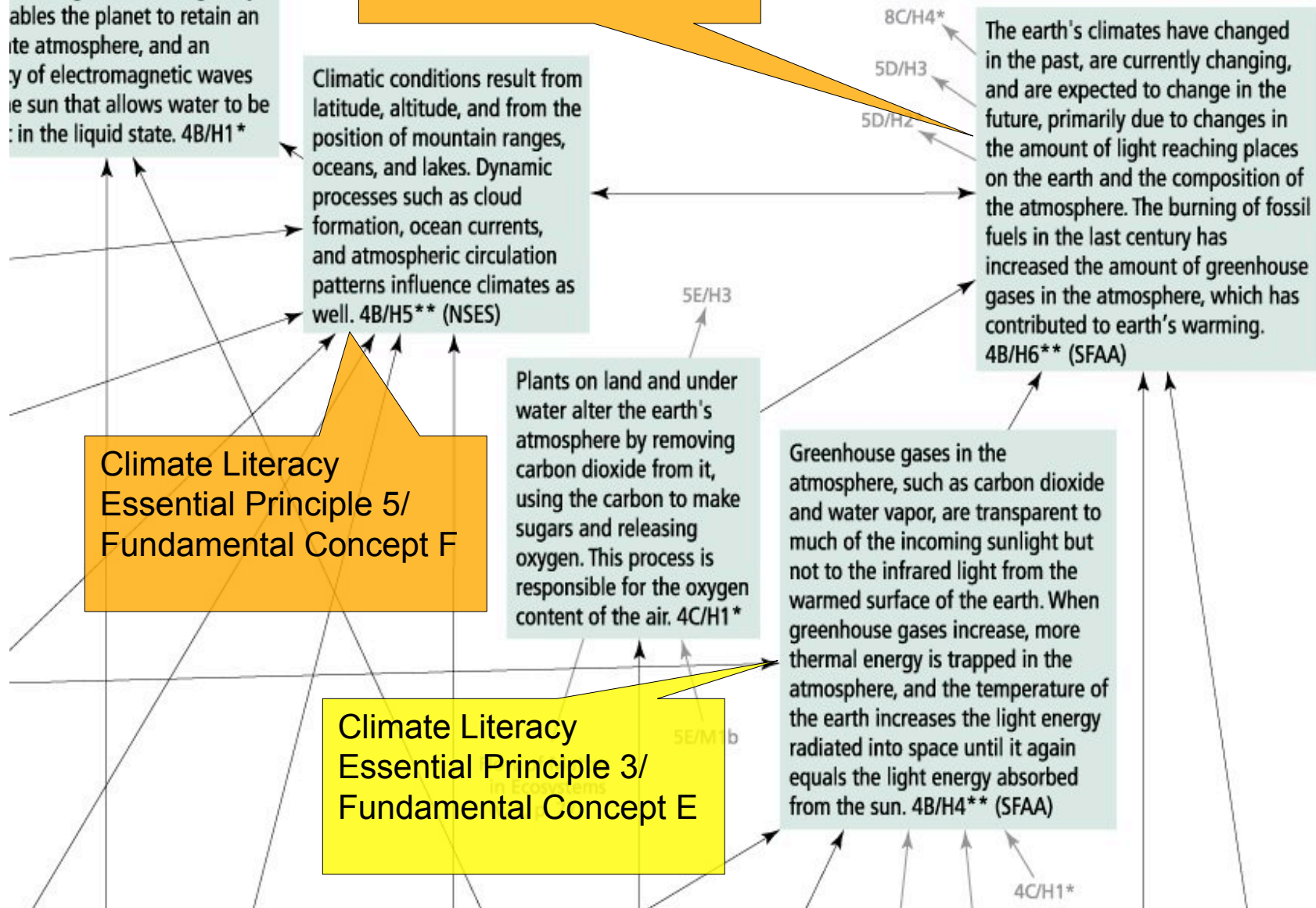
Climate Literacy
Essential Principle 5/
Fundamental Concept F

Plants on land and under
water alter the earth's
atmosphere by removing
carbon dioxide from it,
using the carbon to make
sugars and releasing
oxygen. This process is
responsible for the oxygen
content of the air. 4C/H1*

Climate Literacy
Essential Principle 3/
Fundamental Concept E

The earth's climates have changed
in the past, are currently changing,
and are expected to change in the
future, primarily due to changes in
the amount of light reaching places
on the earth and the composition of
the atmosphere. The burning of fossil
fuels in the last century has
increased the amount of greenhouse
gases in the atmosphere, which has
contributed to earth's warming.
4B/H6** (SFAA)

Greenhouse gases in the
atmosphere, such as carbon dioxide
and water vapor, are transparent to
much of the incoming sunlight but
not to the infrared light from the
warmed surface of the earth. When
greenhouse gases increase, more
thermal energy is trapped in the
atmosphere, and the temperature of
the earth increases the light energy
radiated into space until it again
equals the light energy absorbed
from the sun. 4B/H4** (SFAA)



3

The Sun is the primary source of Earth's energy

DRIVES EARTH SYSTEM

- a. Solar energy heats the atmosphere and water through the global water cycle.
- b. Daily variations of solar energy caused by rotation drive many weather processes.
- c. The tilt of Earth on its axis causes sunlight to be more intensely on different parts of Earth each year, resulting in seasonal changes (Based on AAAS 4B/H3)
- d. Changes in Earth's orbit around the sun over thousands of years alter the amount of solar energy received on Earth and impact long-term climate processes such as Ice Ages
- e. Greenhouse gases in the atmosphere, such as carbon dioxide and water vapor, trap infrared radiation from the warmed surface of Earth, creating a "Greenhouse Effect" which allows liquid water to exist on much of Earth's surface (Based on AAAS 4B/H4)
- f. Sunlight is the ultimate source of most of the energy we use. The energy in fossil fuels such as coal comes from energy that organisms stored through photosynthesis from the sun long ago (Based on AAAS 8C/H8)

4

Earth's weather and climate system are the result of complex interactions between land, ocean, ice and atmosphere.

COMPLEX INTERACTIONS

- a. Solar energy drives Earth's climate system
- b. Earth's land, oceans, and atmosphere transfer heat (energy) differently, creating a dynamic climate system
- c. Earth's atmosphere and ocean are interconnected and impact climate in complex ways
- d. Water cycling is fundamental to climate
- e. The water cycle is closely connected to the carbon cycle through biologic processes like photosynthesis and decay, and climate change
- f. Earth's atmosphere is the primary driver of weather and climate factors such as temperature, air pressure, and wind.
- g. Ocean circulation serves as a thermostat. Changes in the ocean's circulation can lead to large, abrupt changes in climate
- h. Relatively small amounts of greenhouse gases such as carbon dioxide, methane and nitrous oxide, as refrigerants can significantly reduce the Greenhouse Effect.
- i. Human beings are part of Earth's climate system. Human activities can, deliberately or not, alter the equilibrium of the climate system (Based on AAAS, 5D/H3)

5

Earth's weather and climate vary over time and place.

VARIABILITY & CHANGE

- a. "Weather" is the state of the atmosphere at a particular place and time and is influenced by climate and many local factors.
- b. "Climate" describes the prevailing or general weather conditions for an area, or for the entire planet.
- c. Cycles, such as the seasons or weather extremes, can be described by what their cycle length or frequency is, what their highest and lowest values are, and when these values occur. Different cycles range from many years down to a fraction of a second. (Based on AAAS, 11C/M6*)
- d. The temperature of a place on Earth's surface tends to rise and fall in a somewhat predictable pattern every day and over the course of a year. (AAAS 4B/M12)
- e. Differences in the intensity of sunlight warming Earth's surface produce the daily, seasonal and very long-term variations in temperature. (Based on AAAS, 4B/H3b)
- f. Earth's changing climate states are defined by the average temperature, precipitation, humidity, air pressure, and wind, over long timescales. (Based on AAAS, 4B/H5a)
- g. Earth's climate has changed in the past, is currently changing, and is expected to change in the future. (Based on AAAS 4B/M14)
- h. Natural processes that drive Earth's long-term climate change

6

Recent climate change is primarily caused by human activities.

HUMAN ACTIVITIES

- Human beings are a significant part of Earth's climate system.
- Human activities, such as burning fossil fuels and increasing the amount and variety of chemicals released into the atmosphere, reducing the amount of forest cover, and rapidly expanding farming and industrial growth have changed Earth's land, oceans, and atmosphere and altered Earth's climate. (AAAS, 4C/M7a)
- Some changes resulting from human activities have decreased the capacity of the environment to support various species. (Based on AAAS, 4C/M7b)
- The observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in human-induced greenhouse gas concentrations, primarily from fossil fuel combustion and deforestation. (Based on IPCC, 2007)

Source: Ryan Vachon, CTRES Outreach, (303) 735-3641



7

Earth's climate system is influenced by human decisions, which are complex and involve economic costs and social values.



Source: Scott Bauer

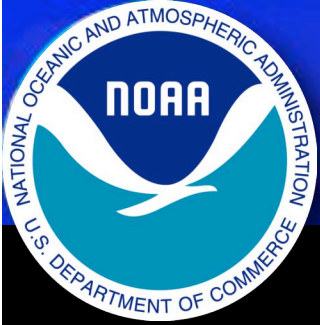
MAKING DECISIONS

- Decisions about the future involve weighing scientific evidence with uncertainties about future economic growth and energy use, costs and opportunities, moral values, and cultural norms.
- Informed decision making is more effective when key assumptions and the basic facts are clearly identified and understood.
- Population growth and industrialization increase demands for energy, potentially improving quality of life but also affecting climate worldwide. (Based on AAAS, 7G/M5)
- The atmosphere is global, and decisions about energy use made in one region affect people and other species worldwide.
- The decisions of one generation both provide and limit the range of possibilities open to the next generation. (Based on AAAS, 7C/H3)
- Decisions about energy use and adapting to climate change are made at all levels, from the individual to the global. (Based on AAAS, 8C/H5)
- Societal change is triggered at the individual and community levels, and by leadership of industry

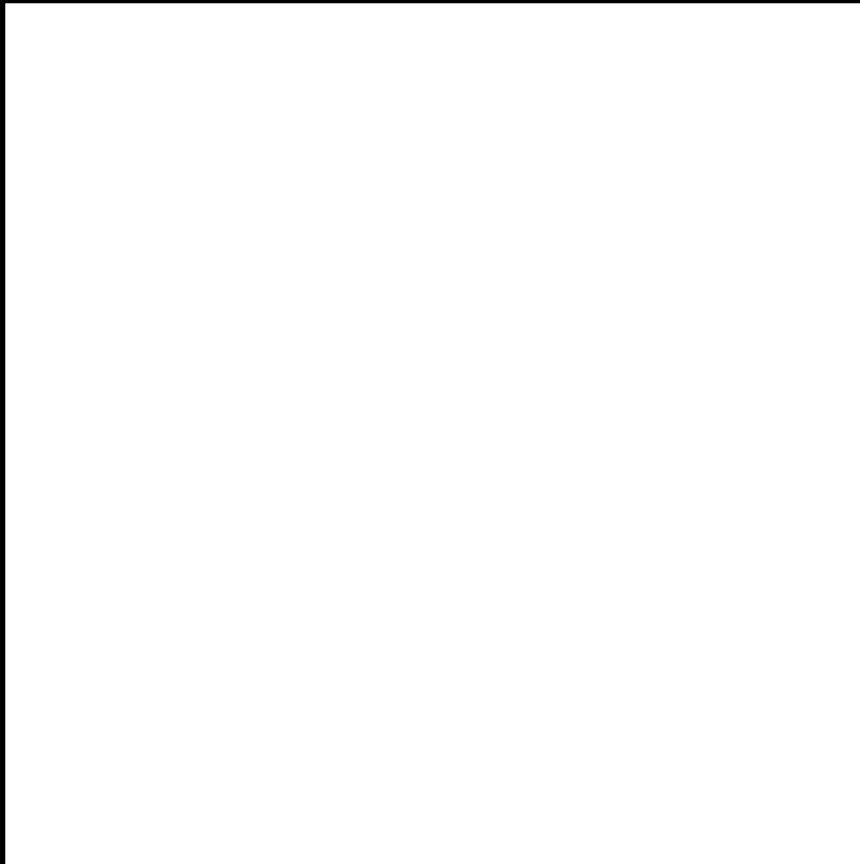


Human Activities & Change





Human Activities & Change





Human Activities & Change





Human Activities & Change





Human Activities & Change





Human Activities & Change





Human Activities & Change





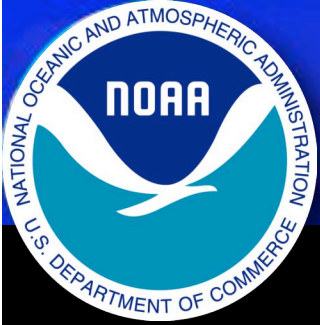
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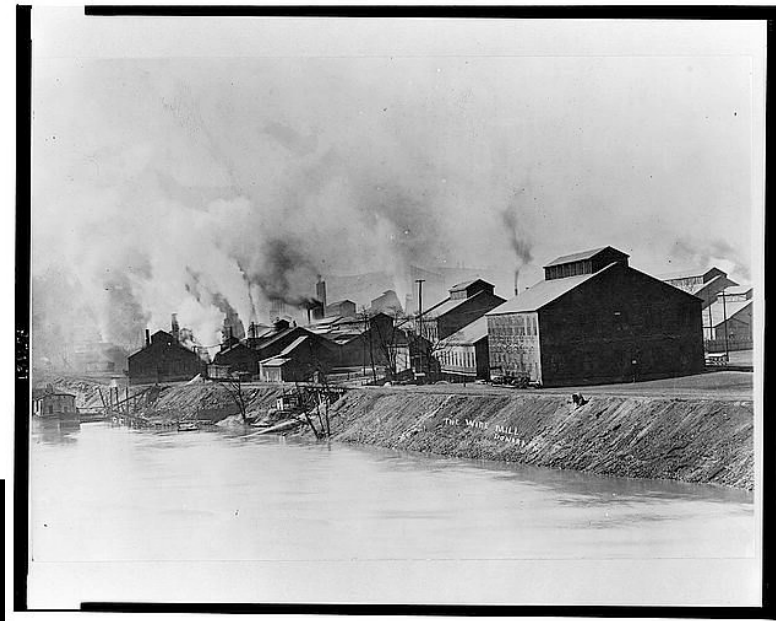


Human Activities & Change





Human Activities & Change



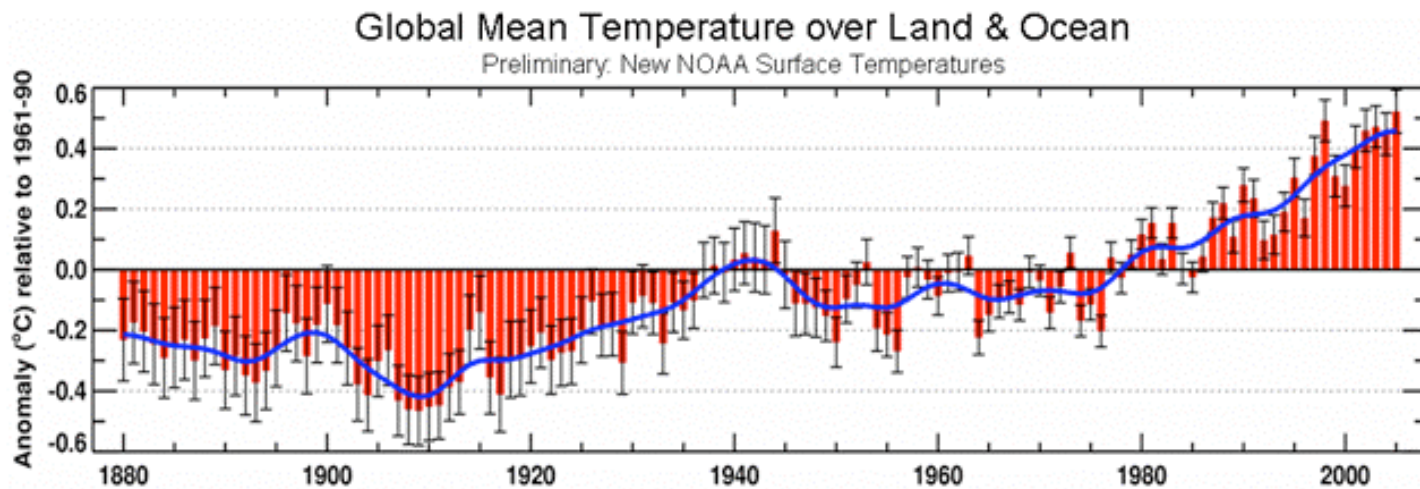


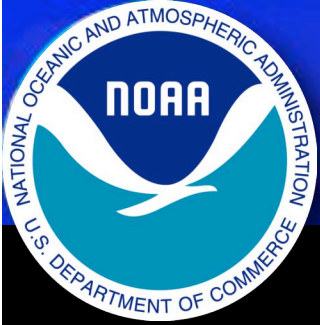
Human Activities & Change



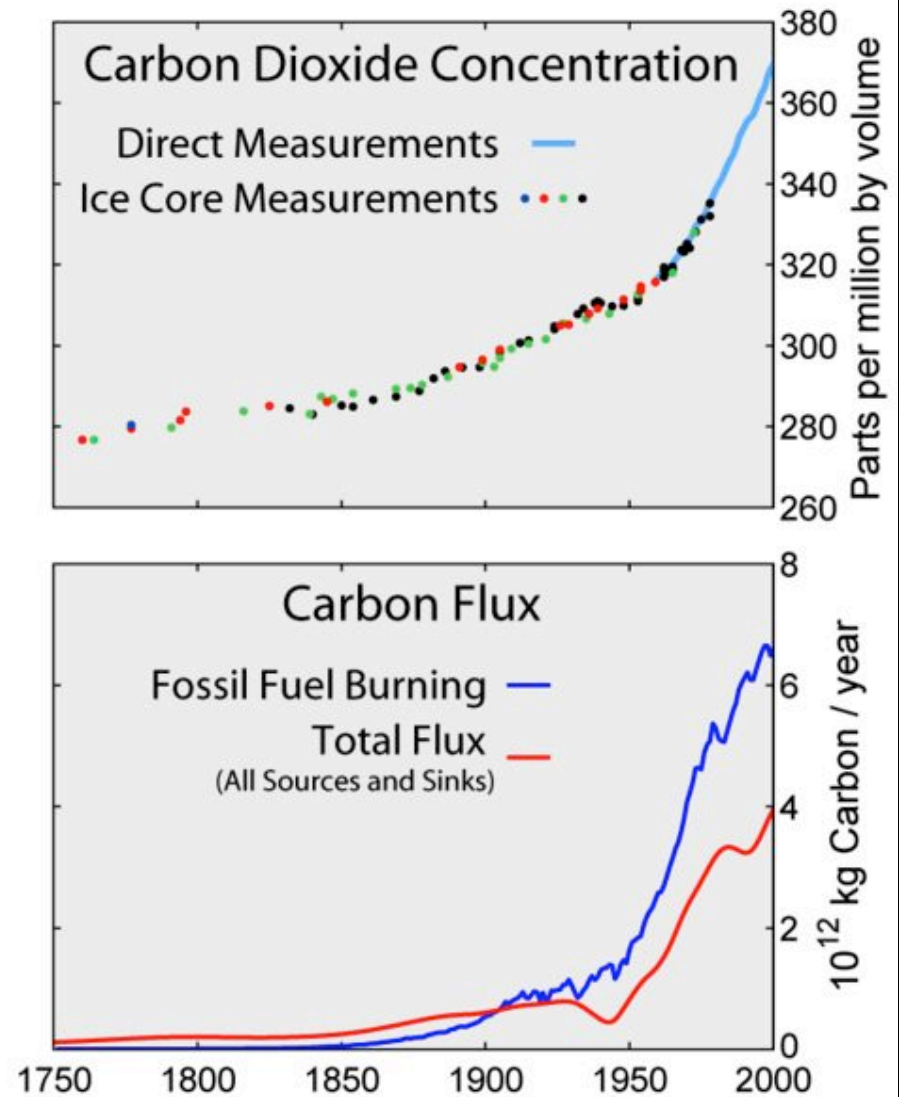


Human Activities & Change



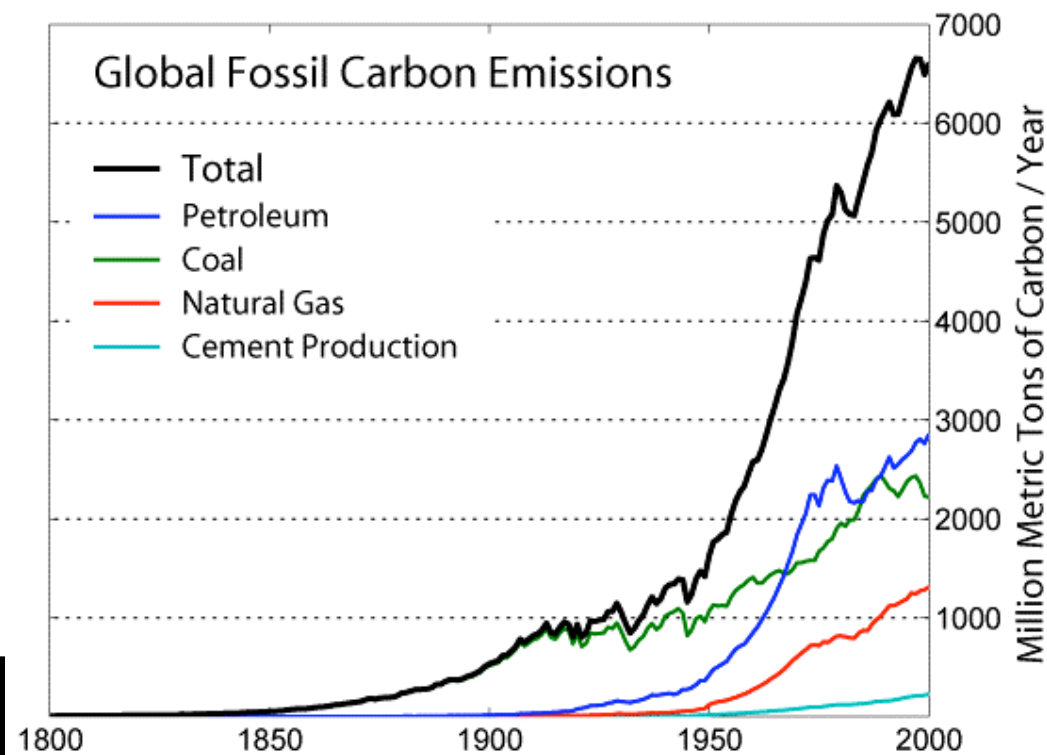


Human Activities & Change



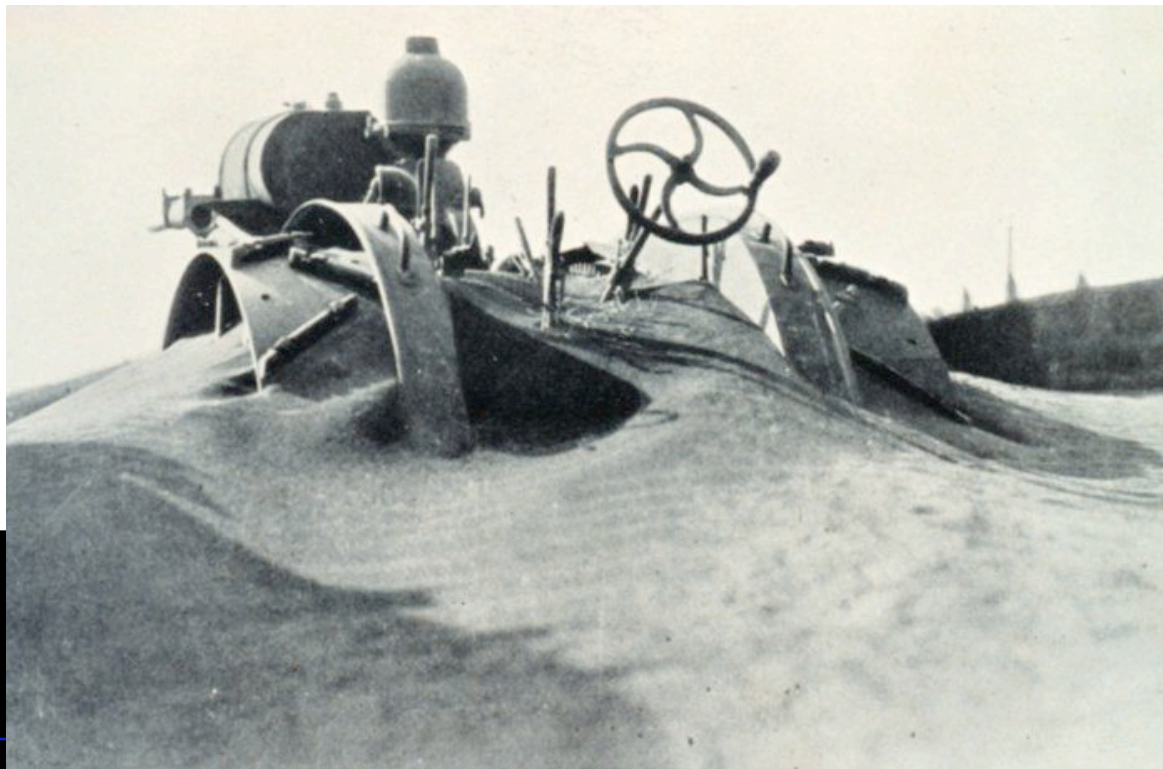


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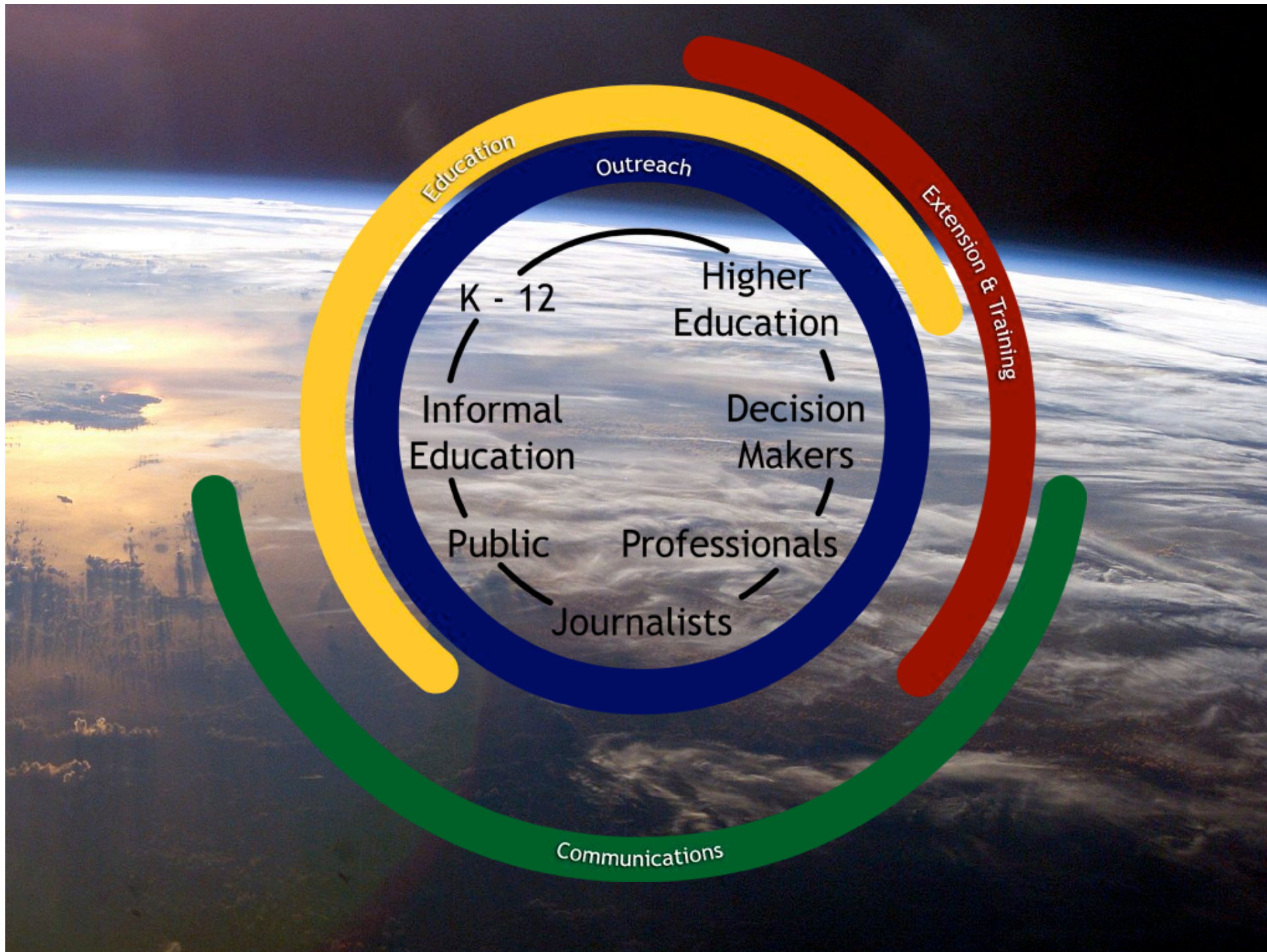




Human Activities & Change



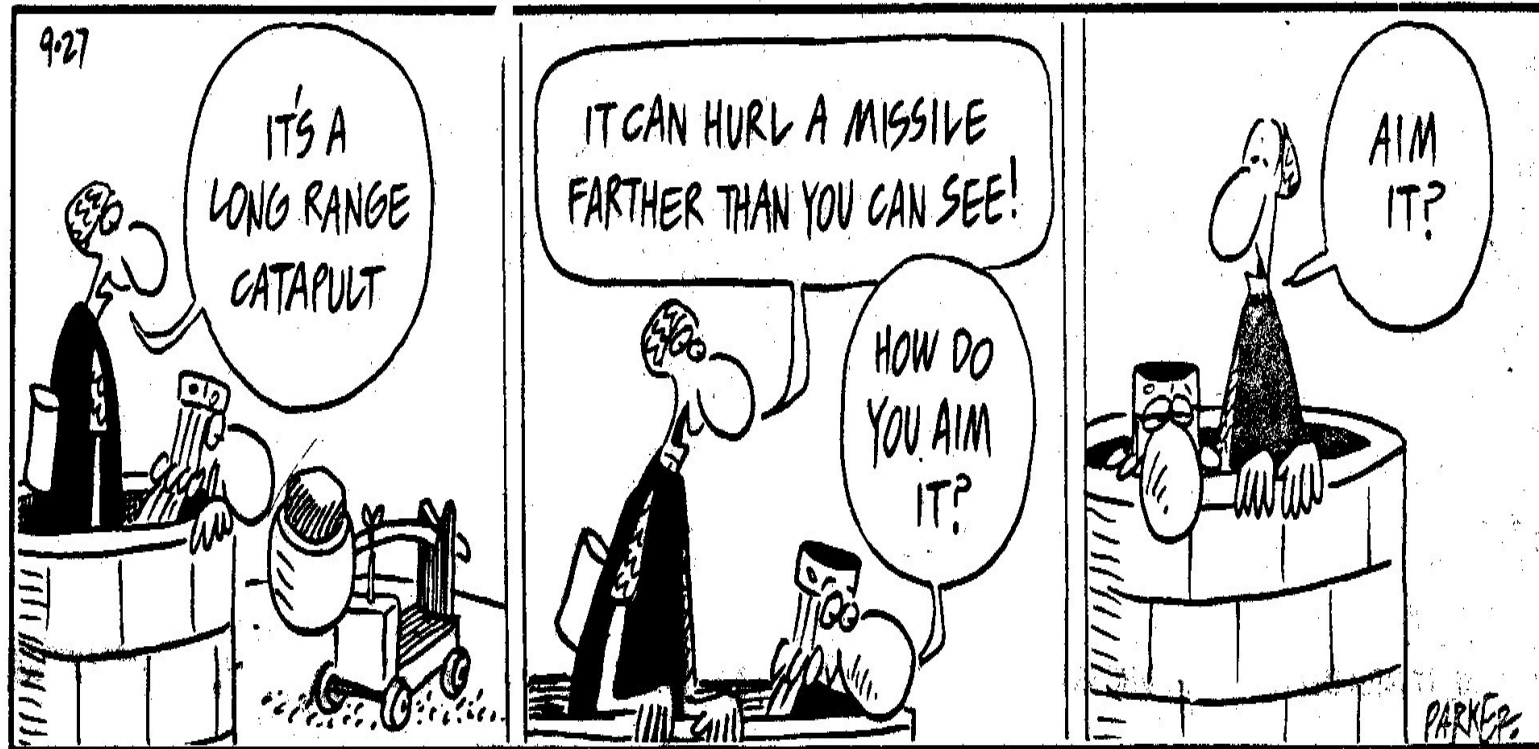


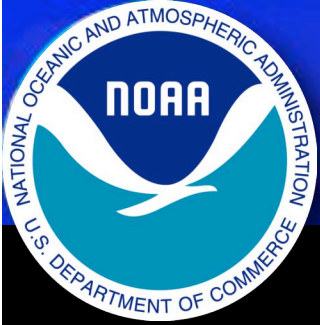




Next Steps

THE WIZARD OF ID PARKER & HART





Align and create educational resources

- **Align to National Science Education Standards and AAAAS Project 22061 Benchmarks for science literacy**
 - **Expand the National Science Digital Library (NSDL) and Digital Library for Earth System Education Stand map project relative to climate literacy**
 - Educational and Scientific review
 - Less is more
 - **Create a gap analysis of educational resources**
 - **Effort coordinated at the interagency level**
-

OCEAN LITERACY: OVERVIEW MATRIX FOR K-12

| Essential Principles Fundamental Concepts | Learning Standards Sub-Concepts | 1. Earth: one big ocean, many features | | | | | | | | 2. Ocean shapes earth | | | | | 3. Influence on weather and climate | | | | | | | 4. Habitable | | 5. Ocean |
|--|---|--|---|---|---|---|---|---|---|-----------------------|---|---|---|---|-------------------------------------|---|---|---|---|---|---|--------------|---|----------|
| | | a | b | c | d | e | f | g | h | a | b | c | d | e | a | b | c | d | e | f | g | a | b | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| EARTH AND SPACE | Systems, Order and Organization | * | * | * | * | * | * | * | * | | | | | | * | * | * | * | * | * | * | * | * | |
| | Evidence, Models and Investigation | | | | | | | | | | | | | | * | * | * | * | * | * | * | * | * | |
| | Change, Constancy and Measurement | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| | Evolution and Equilibrium | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
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| | Objects in the Sky | | | | * | | | | | | | | | | * | * | | | | | | * | * | |
| | Changes in Earth and Sky | | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
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| | Origin and Evolution of the Earth System | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
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| | Populations and Ecosystems | * | | * | * | * | * | * | * | | | | | | * | * | * | * | * | * | * | * | * | * |
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| | The Cell | | | | | | | | | | | | | | * | * | * | * | * | * | * | * | * | * |
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| PHYSICAL SCIENCE | Position and Motion of Objects | | | * | * | * | * | * | * | | | | * | * | * | * | * | * | * | * | * | * | * | * |
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9-12



Life is adapted to conditions on the earth, including the force of gravity that enables the planet to retain an adequate atmosphere, and an intensity of radiation from the sun that allows water to cycle between liquid and vapor.

The earth has a variety of climatic patterns, which consist of different conditions of temperature, precipitation, humidity, wind, air pressure, and other atmospheric phenomena. These patterns result from an interplay of many

Transfer of heat energy at the interfaces of the atmosphere with the land and oceans produces layers at different temperatures in both air and the oceans. These layers rise or sink or mix, giving rise to winds and ocean currents that carry heat energy

Plants alter the earth's atmosphere by removing carbon dioxide from it, using the carbon to make sugars and releasing oxygen. This process is responsible for the oxygen content of the air.



Because the earth turns

6-8



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Grade range: 9 - 12

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Water on the Web

<http://www.nrri.umn.edu/www/index.html>

Scientists collect real-time data and provide it along with 13 lessons for students to learn about water quality and water assessment. Site includes an extensive resource section, Geographic Information System maps, remote sensing information, and tutorials. ~^ The NSDL Middle School Pathway at ENC is an evolving site tailored to the needs of mathematics, science, and technology educators. On the ...

The Water Sourcebooks: K-2

<http://www.epa.gov/safewater/kids/wsb/index.html>

This PDF (requires Acrobat Reader) science site contains a K-2 volume that "explains how the water management cycle affects every aspect of the environment." The book is divided into 5 chapters:

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Life is adapted to conditions on the earth, including the force of gravity that enables the planet to retain an adequate atmosphere, and





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■ NSES Content Standard D Earth and Space Science

■ *Structure of the earth system*

- Water, which covers the majority of the earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the "water cycle." Water evaporates from the earth's surface, rises and cools as it moves to higher elevations, condenses as rain or snow, and falls to the surface where it collects in lakes, oceans, soil, and in rocks underground. ([View full text](#))

■ *Earth in the solar system*

- The sun is the major source of energy for phenomena on the earth's surface, such as growth of plants, winds, ocean currents, and the water cycle. Seasons result from variations in the amount of the sun's energy hitting the surface, due to the tilt of the earth's rotation on its axis and the length of the day. ([View full text](#))



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The earth has a variety of climatic patterns,

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Life is adapted to conditions on the earth, including the force of gravity that enables the planet to retain an adequate atmosphere, and





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 - **Conduct gap analysis**
 - **Complete the teacher professional development**
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-

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This resource has 3 correlations with the National Standards.

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Educational Issues: Inquiry learning, Teacher content knowledge, Teaching strategies

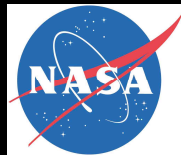
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- Earth Science
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 - The surface of the earth changes.
 - Weather changes from day to day and over the seasons.
 - Weather can be described by measurable quantities, such as temperature, wind direction and speed, and precipitation.

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CLIMATE LITERACY: ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS

DRAFT COMMENT PERIOD; Due 20 December 2007

This guide was developed with input from recent workshops and discussions; this guide reflects the current efforts in defining climate literacy. It is inspired in part by the work conducted by AAAS Project 2061, federal science agencies, educators and other organizations to identify essential principles and fundamental concepts for Ocean Literacy and related work in other areas of Earth systems science education. References associated with particular key understandings are from AAAS Project 2061 benchmarks and other citations.

As a result of the "FRAMEWORK FOR CLIMATE & WEATHER EDUCATION" Workshop, cosponsored by NOAA and AAAS Project 2061 and the "Workshop on Atmospheric Science and Climate Literacy" recently held on November 27 - 29, 2007 by UCAR, AGU, and CIRES, funded by NSF and NOAA, the second and final draft of the "Climate Literacy: Essential Principles and Fundamental Concepts" have been developed.

The [draft](#) (pdf) is open for [comments](#) (doc) and comments are most welcomed.

All reviews/comments are due December 20th.

Note: Please DO NOT INSERT COMMENTS INTO THE PDF.

Send comments to frank.niepold@noaa.gov.

Due 20 December 2007

This Climate Literacy: Essential Principles and Fundamental Concepts draft was primarily developed by Mark McCaffrey, CIRES and Frank Niepold NOAA/UCAR.

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